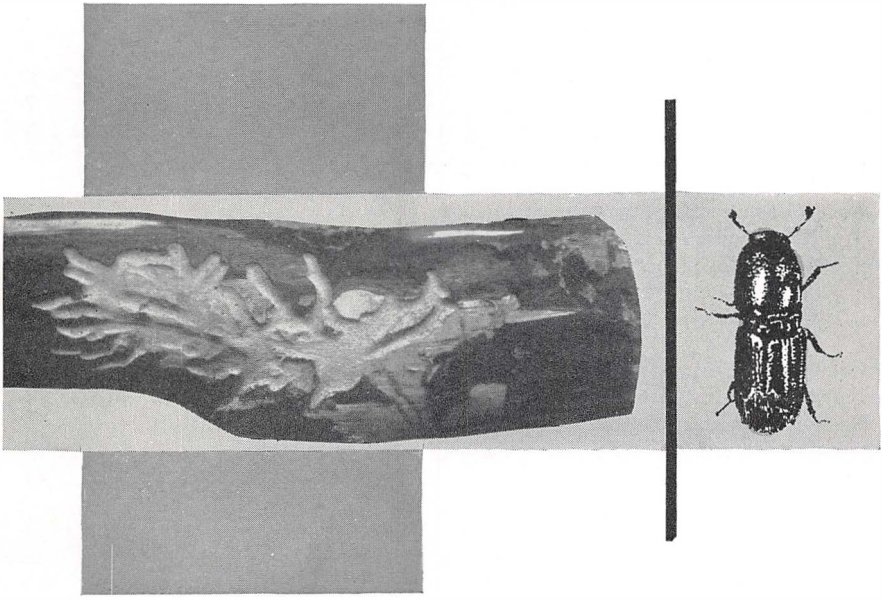
the California
Five-Spined Engraver
its biology and control



by George R. Struble
and Ralph C. Hall

Circular No. 964

U. S. Department of Agriculture
Washington, D. C.

CONTENTS

	Page
Enemy of reserve and second-growth ponderosa pine	1
Character of outbreaks	3
Seasonal history and habits	6
Methods of attack	6
Generations and brood stages	7
Number and sex ratio of emerging beetles	8
Attack periods	10
Adult food habits	10
Conditions affecting brood development	11
Host characteristics	11
Amount of phloem moisture	12
Seasonal temperature conditions	13
Winter precipitation	14
Presence of yeasts and blue-stain fungi	14
Conditions affecting outbreaks	14
Biological control factors	16
Control methods	18
Summary	19
Literature cited	21

Washington, D. C. August 1955

For sale by the Superintendent of Documents - - - - - - - - - Price 15 cents

the California

Five-Spined Engraver

Its Biology and Control

By *George R. Struble* and *Ralph C. Hall*, entomologists, California Forest and Range Experiment Station,[1] Forest Service

ENEMY OF RESERVE AND SECOND-GROWTH PONDEROSA PINE

The California five-spined engraver (*Ips confusus* (Lec.)) is one of the most destructive killers of young pine forests in California and southern Oregon. Its greatest damage is to ponderosa pine trees from sapling to small sawlog size up to 24 inches diameter breast high, and to the tops of larger trees (fig. 1). This insect also causes much damage to other pine species that occur within its range. Attacks are primarily by beetles reared during the spring and early summer in fresh slash caused by logging, snow breakage, or land clearing. The beetles infest living trees nearby from midsummer to late fall when breeding conditions and other factors are favorable.

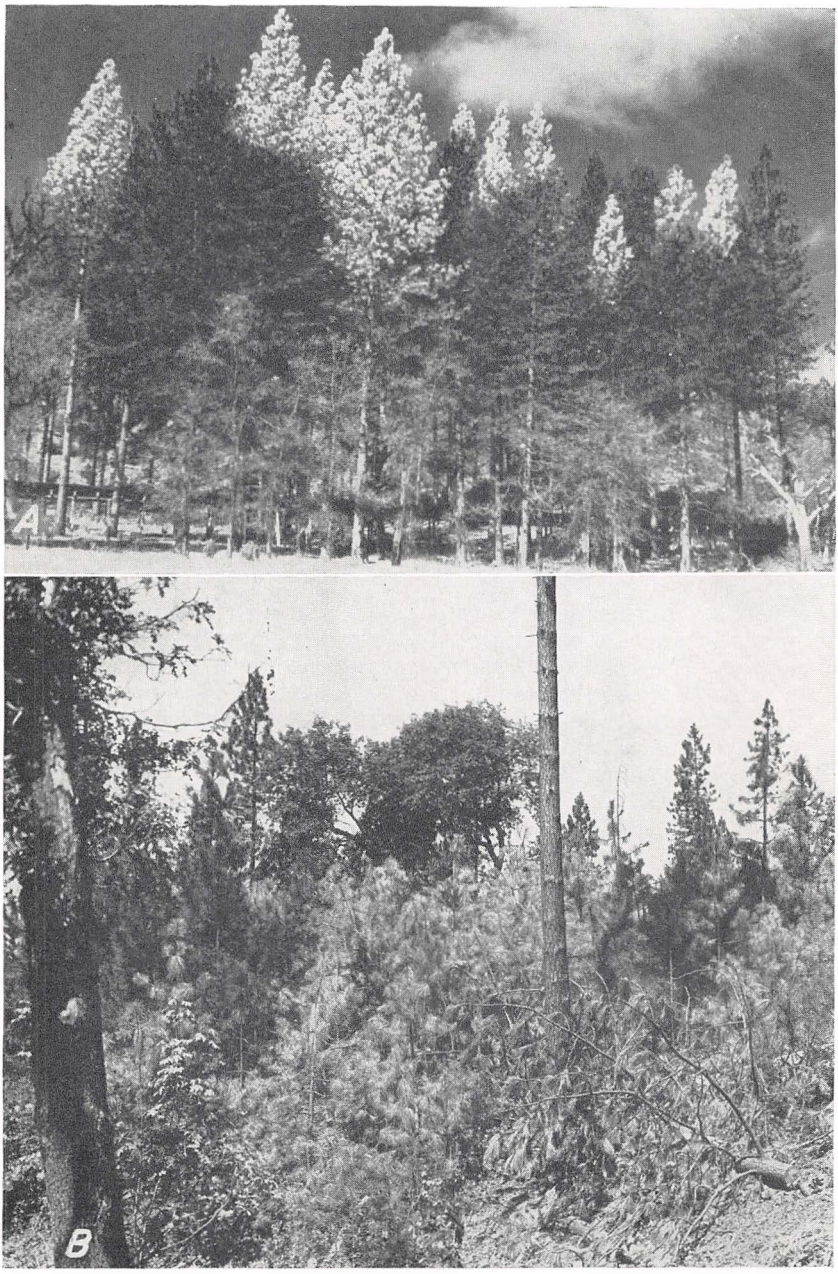
The five-spined engraver occurs from the Rogue River drainage along the west slope of the Cascades in southern Oregon to the Laguna Mountains in southern California. Specific California locations include Moffat Creek, and Klamath, Trinity, Sacramento, and Pit Rivers in northern California; west slope of Sierra from Feather to Kern Rivers; Coast Range, including Stony Creek, Cobb Mountain, Mount Hamilton, Santa Cruz Mountains, Carmel River, and Figueroa Mountain; southern California at Tejon Pass, San Bernardino Mountains, Pine Hills, and Laguna Mountains. Oregon locations include timbered areas in the vicinity of Ashland and Applegate.

Published information reports that all pine species within the range of this bark beetle are attacked (*3, p. 87, 6*).[2] The principal hosts include pondersosa pine (*Pinus ponderosa* Laws.), Coulter pine (*P. coulteri* D. Don), Monterey pine (*P. radiata* D. Don), sugar pine (*P. lambertiana* Dougl.), western white pine (*P. monticola* Dougl.), knobcone pine (*P. attenuata* Lemm.), foxtail pine (*P. balfouriana* Grev. & Balf.), Jeffrey pine (*P. jeffreyi* Grev. & Balf.), singleleaf pinyon (*P. monophylla* Torr. & Frém.), and Digger pine (*P. sabiniana* Dougl.). Unsuccessful attacks have been recorded in incense-cedar (*Libocedrus decurrens* Torr.) and white fir (*Abies concolor* (Gord. & Glend.) Lindl.).

No reliable estimate of the economic loss caused by the five-spined engraver is possible because its attacks vary in habit and are often closely associated with those of the western pine beetle (*Dendroctonus*

[1] Maintained by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California, at Berkeley, Calif.

[2] Italic numbers in parentheses refer to Literature Cited, p. 21.



F-476685, 476686

Figure 1.—*A*, Top-kill infestation by the California five-spined engraver in young merchantable-size ponderosa pine. Fading crowns are most prevalent during late summer and fall. *B*, Ponderosa pine saplings killed by adult beetles during midsummer. This is part of a 500-tree group within an area logged in the spring.

brevicomis Lec.), the principal insect enemy of ponderosa pine. Attacks by the five-spined engraver are confined primarily to small stems that are rarely more than 24 inches in diameter. This insect frequently kills 100 or more saplings and poles at one time, and sometimes as many as 500. Often it attacks only the tops and limbs of larger trees, and is followed quickly by the western pine beetle which attacks the main bole. Sporadic outbreaks by the five-spined engraver alone from 1944 to 1949 in ponderosa pine at elevations ranging between 2,000 and 4,500 feet throughout California resulted in losses estimated to be in excess of 200 million board-feet.

The aggressive characteristics of this engraver beetle have been known for nearly half a century (*3, p. 87, 4, 6*), and much progress has been made in the recognition of attacks and in the management of slash in cutover areas to lessen the hazard of this and other *Ips* species (*2*). Its potentialities for damage have been brought more sharply into focus by a rising lumber market and more intensive forestry during and since World War II.

The 1944 outbreak in northern California near Mount Shasta was followed by many others along the entire western slope of the Sierra Nevada, in the interior Coast Range, and in southern California. All of these outbreaks were closely associated with logging or land clearing from 1944 to 1949 and gave sufficient proof of the need for special investigative effort to provide a sounder basis for combating the destructiveness of the California five-spined engraver. Since 1945, research has been conducted on the biology, habits, ecology, and control of this insect, and on some of the ecological factors affecting host-tree resistance in the divergent ponderosa pine types found from northern to southern California. The studies were centered at Hat Creek in northern California, Miami Field Base in the central and southern Sierra, and Julian in southern California mountains (fig. 2).

This report presents the more pertinent facts gleaned from these special studies from 1945 to 1951. While many gaps are still to be filled by additional research, the information at hand should provide a better understanding of the problem and aid in management of affected pine areas to lessen the hazard.

CHARACTER OF OUTBREAKS

Although a complete understanding of the specific combination of conditions most favorable to outbreaks of the five-spined engraver has not yet been attained, it has long been recognized that the combination of abundant fresh slash (fig. 3, *A*) and stands of drought-weakened trees is the setting contributing most to intensive killing (*2, 6*). Stand injuries resulting from fires, or stand weakness induced by flooding, are of lesser importance. Disturbances in timber caused by logging and the resultant accumulated slash (fig. 3, *B*) attract beetles and tend to concentrate populations. However, it is not understood why at times only a few trees are killed when slash is abundant and beetle populations are heavy, and at other times outbreaks start in the absence of slash.

As a general rule, outbreaks are sporadic and short-lived; they seldom persist in a given area much longer than a year. The beetles

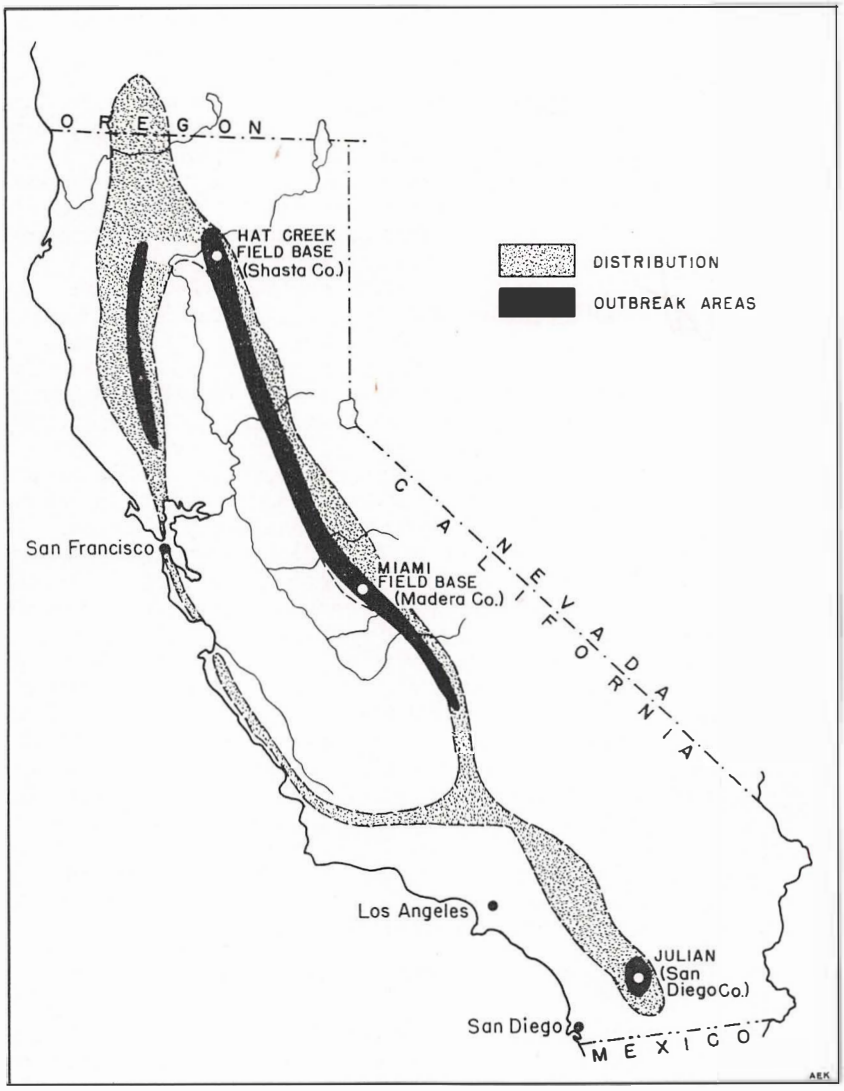
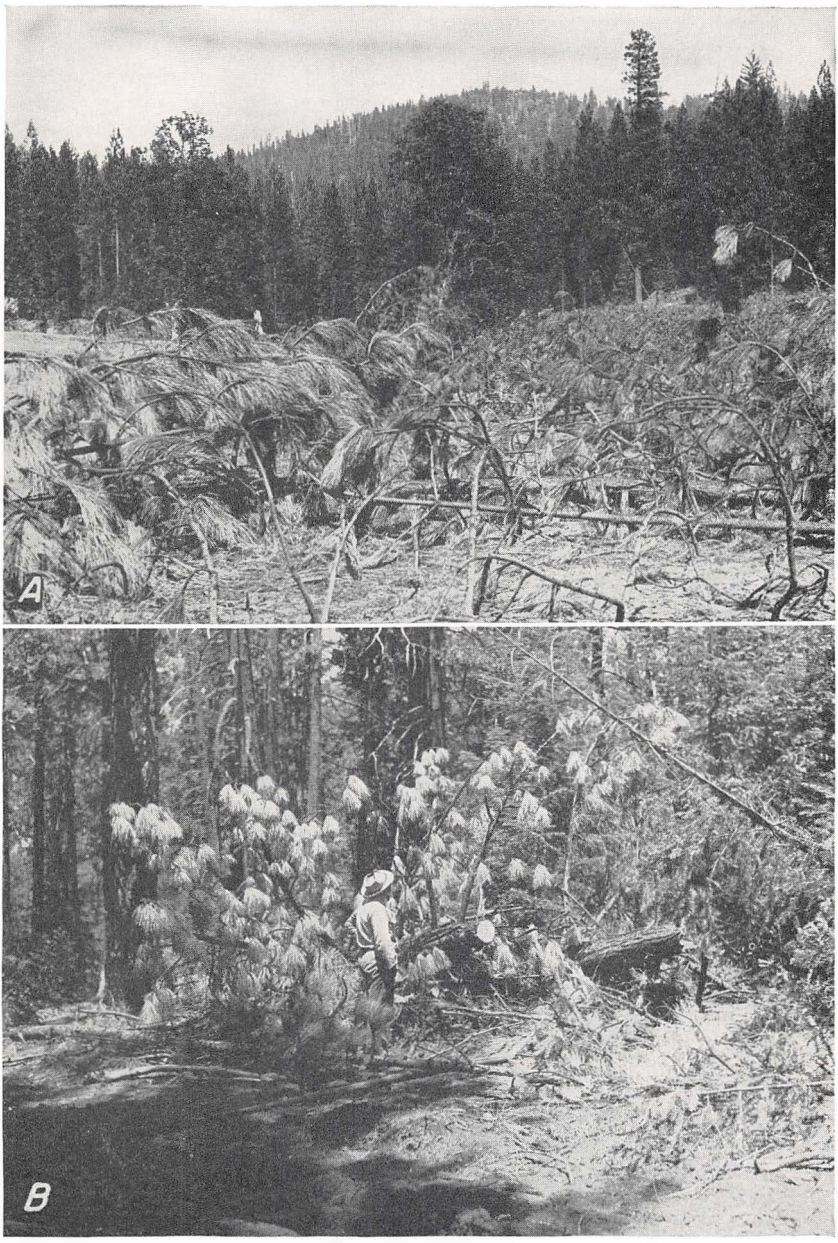


Figure 2.—Distribution and outbreak areas of the California five-spined engraver beetle.

appear suddenly from midsummer through fall and disappear almost as rapidly the next year, occasionally continuing into the second or even third year when associated with aggressive attacks of the western pine beetle. Numerous examples of outbreaks were recorded between 1912 and 1940, many of them associated with windfalls, snowbreak, and slash, and several preceding western pine beetle outbreaks. The periods 1912–13, 1914–16, and 1929–32 were notable for outbreaks of the five-spined engraver. In 1932, after 2 years of heavy top-killing associated with a western pine beetle epidemic throughout California



F-476687, 476688

Figure 3.—A, Slash resulting from land clearing during April, May, and June in second-growth ponderosa pine, Mariposa County. Numerous adult five-spined engravers were reared here. *B,* Unlopped ponderosa pine tops left after logging, Shasta County. This type of slash favors optimum brood development, especially when trees are felled in late winter, spring, and early summer.

pine forests, the engraver beetle dropped abruptly into relative obscurity, not reappearing until 1939 and 1940.

The most recent period, 1944 to 1951, presented a similar pattern. The outbreak near Mount Shasta in northern California, which carried over into the second year, was the longest of any recorded for this period. The principal difference between the recent and past outbreaks was that the 1944 to 1951 period was characterized by unprecedented logging activity in young-growth ponderosa pine, which resulted in great accumulations of slash suitable to engraver beetle breeding.

Western pine beetle infestations commonly follow engraver beetle outbreaks. Light infestations of the western pine beetle during the first year of engraver beetle attack, and heavy infestations the next year, have been observed repeatedly. An outstanding example of this sequence was the engraver beetle top-killing preceding the 1929–32 western pine beetle epidemic. Other examples among recent outbreaks in California occurred at Burney-McCloud (Shasta County); Cobb Mountain (Lake County); Jerseydale (Mariposa County); Arrowhead-Crestline (San Bernardino County); and Julian (San Diego County).

Although five-spined engraver outbreaks are short-lived and do not often cause severe volume losses, they weaken stands sufficiently to allow the western pine beetle population to build up markedly. This sequence of insect attack could result in very serious stand depletion. Decisions to control engraver beetle infestations, therefore, are based on the threat of subsequent western pine beetle activity.

SEASONAL HISTORY AND HABITS

Methods of Attack

Attacks by the engraver beetle occur along the main upper stem and larger branches in older trees and extend downward to the ground in young trees. The first entry is usually made where branches join the main stem, through tiny round holes that penetrate to the sapwood. Later attacks are made along the stem between whorls of branches. In fresh slash the first attacks are made in the top part of the main stem; these attacks are followed by indiscriminate entries in all shaded parts of the stem and in branches more than 3 inches in diameter.

The male beetle bores a round nuptial chamber 2 to 3 times his size in the soft inner bark or phloem, often grooving the surface of the sapwood. After 24 to 48 hours, he is followed by 2 to 5 females (usually 3), each of which bores an individual egg tunnel or gallery in a pattern resembling an inverted tuning fork. When complete, each gallery extends 4 to 6 inches from the nuptial chamber, parallel to the grain and lightly grooving the sapwood. Because borings and frass are pushed outside constantly, the galleries remain open tunnels.

The number of attacks in trees or slash varies from 2 to 24 per square foot of inner bark surface, but the average number is 8 to 12. Variations in number of tunnels per entry depend on the number of females; hence, there may be as few as 1 or as many as 5 tunnels per attack. The total length of egg tunnels bored per square foot of bark area may vary from less than 40 to more than 100 inches. Measure-

ments in large quantities of logging slash on the Sierra National Forest from 1946 to 1948 revealed the average length of tunnels per square foot of bark area to be 68.2 inches, from an average number of 9.40 attacks.

Because entrance holes and egg galleries are kept open, reddish accumulations of sawdustlike material pile up in branch axils and bark crevices. In slash this material occurs as conical mounds along upper surfaces. Pitch tubes are rare.

Often, more than 50 percent of the adults originating attacks in slash emerge to reattack and establish a second brood. This habit was demonstrated in 1933.[3] Controlled experiments in 1947 revealed that (1) reattack takes place about 20 days after the first attack; (2) the amount of reemergence is evidently related to overcrowding and dwindling of food supply.

Generations and Brood Stages

The number of seasonal generations varies from 2 per year in the northerly limits of the range to as many as 5 per year in the south, with an average of 3 to 4. One generation more or less than the average for a locality is likely to occur in any given year owing to seasonal variations in temperature which cause acceleration or retardation in development. The typical development period within the middle latitudes of distribution is illustrated by figure 4. The dates and duration of each generation are tabulated as follows:

Generation:	*Date of initial attack*	*Date of peak emergence*	*Days to complete cycle*
I	Apr. 15	June 15	60
II	June 10	Aug. 1	50
III	July 25	Sept. 10	45
IV	Sept. 1	-------	-----

Adult.—As described by other authors (*3, p. 87, 6, 11, pp. 108–113*), this insect in the adult stage (fig. 5) is reddish-brown to pitch black, 4 to 4.5 mm. long, with 5 spines on the elytral declivity, and the declivital face finely hairy. Observations of thousands of emerged specimens in recent studies confirm these descriptions. Pitch black is the characteristic color of mature specimens. The adult life period varies with temperature conditions and food supply. At temperatures ranging from 60° to 90° F. the survival of adults confined without food varied from 7 to 14 days. The normal survival period within this range in fresh slash or in trees is 4 to 8 weeks. Under the varying temperatures prevailing from fall until the next spring, mostly between 30° and 60°, the span of life is 4 to 8 months.

Eggs.—The eggs are ovoid-cylindrical, pearly white, and average 0.5 mm. wide by 1 mm. long. They are deposited in individual niches along the sides of the egg galleries and number about 10 to the inch. They hatch in 5 to 14 days in spring and summer.

Larvae.—The larvae are legless grubs with light-yellow heads and light-ivory bodies, and are 4 to 4.5 mm. long when fully developed. They mine in individual tunnels within the inner phloem, which

[3] FURNISS, R. L. STUDIES OF *Ips confusus*. Bass Lake, Calif. (Manuscript report.) U. S. Forest Service, Calif. Forest & Range Expt. Sta., Berkeley, Calif. 1933.

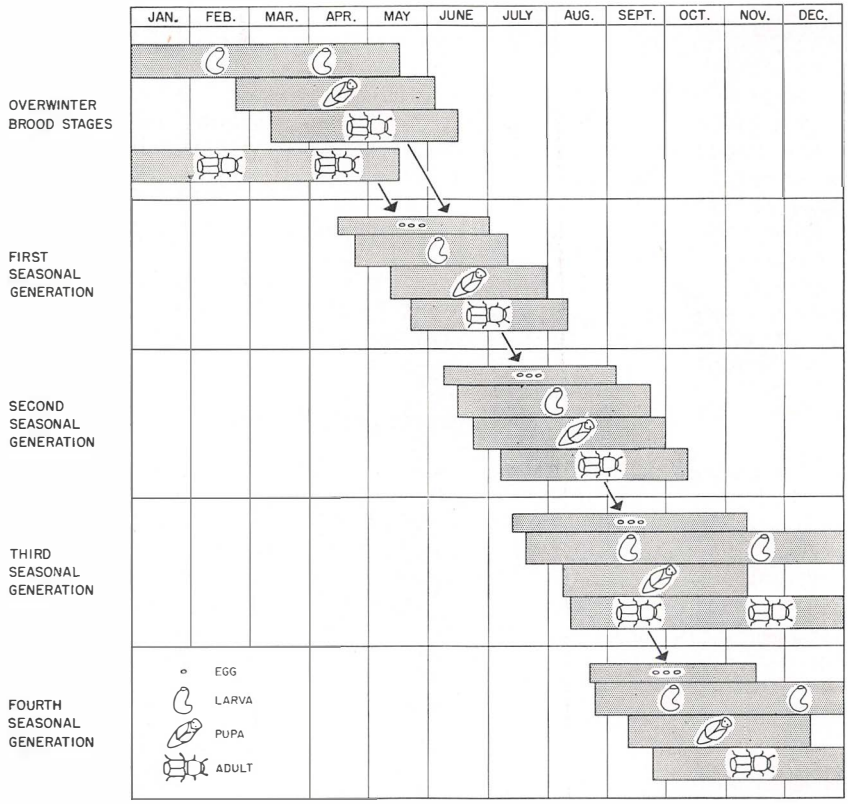


Figure 4.—A typical seasonal history in midrange of the California five-spined engraver.

results in destruction of this tissue and death to the vital cambium layer of the tree. The average period for development to full size at temperatures above 65° F. is 3 weeks; the range is from 2 to 5 weeks. Dormancy is induced at temperatures below 40°, but slow development continues at temperatures from 40° to 60°.

Pupae.—The color of pupae is light ivory at first, and it darkens with development. Pupae are 4.0 to 6.0 mm. long, quiescent, and embryonic. This stage transforms to the adult in 7 to 14 days at temperatures above 60° F.

The predominant overwintering stages consist of young to mature adults, pupae, and mature larvae, which remain dormant beneath the bark of the host. When temperatures rise above 65° F. in the spring, the larvae and pupae resume development and the adults emerge, often as early as March 15.

Number and Sex Ratio of Emerging Beetles

Before emergence, mature adults tend to congregate, and several beetles may use a single exit hole. In a demonstration conducted by attaching glass vials to an infested log, from 1 to 4 adults were found emerging from the same exit hole.

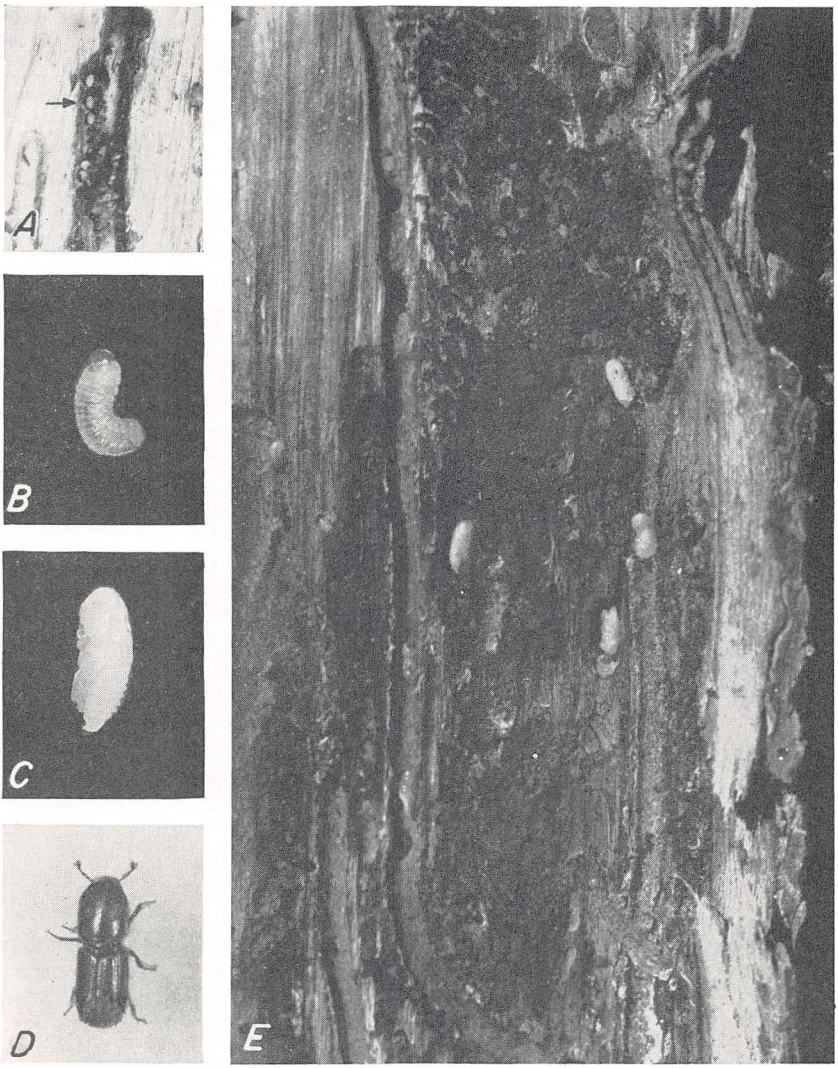


Figure 5.—Stages and habitat of the California five-spined engraver: *A*, Eggs packed in niches in phloem along the egg gallery, *X* 2; *B*, larva, *X* 3; *C*, pupa, *X* 3; *D*, adult, *X* 3; E, inner bark surface showing egg tunnel, larvae and pupae in cells, *X* 1.2.

The number of adults that reach maturity and emerge from infested slash or standing trees varies considerably from year to year and from season to season, even though the character of slash or conditions of breeding may be similar. Rearing records were maintained in the southern Sierra Nevada from 1946 to 1951 (137 samples containing 335 square feet of bark surface). These records showed an average emergence of 141 adults per square foot, the range being from 30 to 307 adults. In general, emergence was heavier from slash in spring or early summer than from slash or infested trees later in the season.

The ratio between emerging males and females is 1:1.3; between attacking males and females it is 1:3.0. This determination is based on microscopic examinations of sex characteristics on 1,680 newly emerged adults from spring and summer broods and 340 parent beetles from attacked trees and slash.

The ratio between parent and progeny varies among different broods of a given season and among those produced in different seasons. Limited records from 1946 to 1951 in the southern Sierra areas revealed that the average number of progeny produced in 1947, an outbreak year, was nearly 8 times that of the attacking parents, while in 1950 it was 2.5 times the number of attacking parents and no outbreaks occurred. The progeny production ratio for these years was as follows: 1946, 5.4; 1947, 7.6; 1948, 4.2; 1949, 3.2; 1950, 2.5; and 1951, 3.3. This period was characterized by heavy outbreaks in both 1946 and 1947 and a light outbreak in 1949.

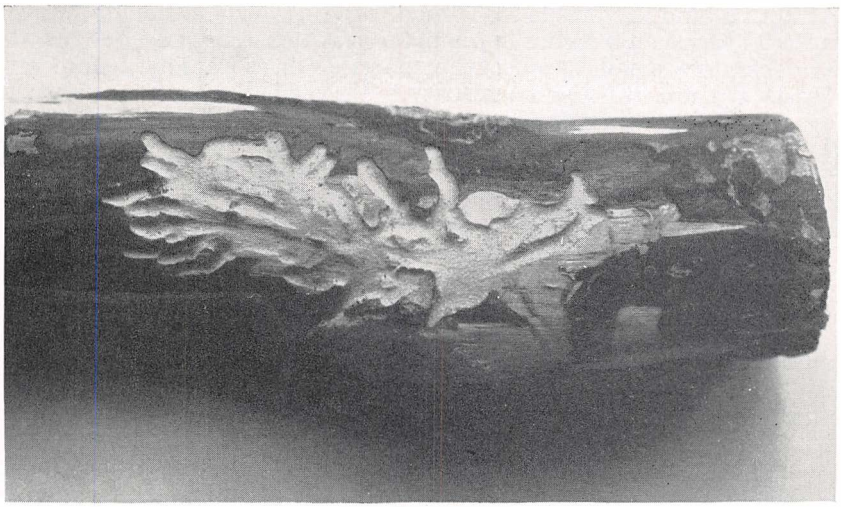
Attack Periods

Because the different brood stages overlap greatly, attacks may occur continuously from mid-March to mid-November in certain parts of the range of the beetle. Development of the various stages usually continues from mid-April to mid-October in the median range of the beetle, at latitudes approximately 35° to 40° N. and elevations between 2,500 and 4,500 feet. Here there are 3 or 4 distinct periods when attacks occur in abundance, and each period corresponds with the emergence and flight peak of a given generation. They are: May 1 to 15, from overwintered broods; June 15 to 30, from Generation I broods; August 1 to 15, from Generation II broods; September 10 to October 1, from Generation III. One additional generation may occur in the more southerly, and one less generation in the more northerly limits of the range, owing to climatic differences.

Adult Food Habits

In normal attacks, adults feed on the fresh phloem material as they bore egg tunnels. However, mass attacks for feeding alone are commonly made in dense stands of saplings and small poles (fig. 6). One or more examples of this mass feeding habit occur nearly every year during midsummer and fall. Trees so attacked in midsummer are abandoned within 2 to 3 weeks; those attacked in the fall usually harbor the adults until the following spring. In all such trees, concentrations of beetles range from less than 300 to more than 500 adults per square foot of bark surface in the main stem, from root crown to the tip. This mass-attack habit is interpreted as a feeding requirement, since the inner bark and sapwood surfaces are quickly grooved by countless feeding tunnels and broods are rarely produced. Its significance is not fully understood.[4]

[4] Similar habits of other species of *Ips* appear to be fairly common. J. M. Miller (Hopkins' U. S. 17489) in 1928 found mass feeding by *I. lecontei* near Prescott, Ariz. F. P. Keen (*8*) refers to attack in living trees by several species of *Ips* and *Pityophthorus* as hibernating habit.



F-476690

Figure 6.—Adult engravings on sapwood surface of a ponderosa pine sapling killed by the California five-spined engraver in midsummer. This is the result of mass feeding in small-sized trees.

CONDITIONS AFFECTING BROOD DEVELOPMENT

Host Characteristics

The development and growth to maturity of broods depends a great deal on the quality and character of the host. The largest and most vigorous broods are produced in fresh slash; old soured or partially dry slash is unfavorable as a rearing medium. Phloem and bark thickness, stem diameter, and even the age of trees may influence the development and size of broods. Also, some differences exist between the broods produced in slash and living trees.

Slash

Freshness.—Concentrations of freshly cut slash left on the ground in full or partial shade as a result of logging operations during the late winter, spring, and early summer are most favorable to breeding. These concentrations are attacked heavily by overwintering adults as they emerge in the spring, and the result is production of large numbers of progeny. Green slash that escapes attack and is left on the ground longer than 3 months after late fall felling is unfavorable to the production of large broods, even though attacked heavily the next spring.

Type and diameter.—Logging slash most commonly attacked can be grouped into 3 distinct types: (1) unlopped treetops varying in basal diameter from 10 to 20 or more inches; (2) limbs lopped from utilized logs or from tops; (3) large logs (culls or butts) up to 40 inches in diameter. The first type, unlopped material, is by far the most

attractive and favorable to brood production. Although lopped material less than 3 inches in diameter is attacked heavily, the broods produced are small because the material dries rapidly before the insects are able to reach maturity. Very small broods develop in large logs even when the logs are heavily attacked; the reasons for this have not been determined.

Bark and phloem thickness.—The preferred bark thickness, beneath which attacks most often occur and in which the largest broods are produced, varies from ¼ to ½ inch. Vigorous broods may be found, however, in bark as thin as ⅛ inch and as thick as ¾ inch. Bark more than 1 inch thick is seldom attacked. Phloem as thin as 1/16 inch was found to be as productive of broods as phloem 3 times as thick.

Age of host tree.—The beetle populations developed in slash from old and young ponderosa pine trees differed on the eastern slopes of the Sierra Nevada. In this interior type, slash from trees 75 years old produced 4 times as many beetles as slash from trees estimated to be 450 years old. Along the western Sierra Nevada slopes and in other mountain ranges where this insect is distributed (the westside type), the populations did not differ with age of tree; slash from trees 475 years old produced broods equivalent to those in slash from trees 75 years old. This difference between the two ponderosa pine types is believed to be due to variations in the nutritional qualities of the phloem.

Living Trees

Lack of association between tree growth rate and California five-spined engraver attacks was indicated by measurement of increment cores taken from infested trees in 1930.[5] This was further substantiated during 1947 and 1948 in northern California by measurements obtained by means of tree-growth bands attached to 5 pole-size trees. The measurements revealed more rapid growth in 1947 when there was heavy killing than in 1948 when killing was nominal. Although not conclusive, this information suggests that the rate of tree growth is of minor importance in engraver attacks.

Amount of Phloem Moisture

The influence of phloem moisture in slash on the development of broods was studied in some detail, but no positive relationship was shown. This was because of great moisture variations among samples, even among those in close proximity to each other, and insufficient replications. Moisture content was determined by ovendrying disks cut from phloem of logs and slash. The results showed that (1) phloem moisture ranging from 125 to 150 percent of dry weight appeared to be optimum for brood success among log samples varying between 50 and 190 percent moisture; (2) significant differences in brood success in slash from sites I and II ponderosa pine could not be accounted for by differences in phloem moisture; (3) no consistent

[5] SALMAN, K. A. FOREST INSECT CONDITIONS, KINGS CANYON RANGER DISTRICT, SEQUOIA NATIONAL FOREST. (Manuscript report.) U. S. Forest Serv. Calif. Forest & Range Expt. Sta., Berkeley, Calif. December 1930.

correlations were evident between the number of beetles produced in lopped and unlopped tops, even though consistent differences in phloem moisture were shown. This work strongly suggested that factors other than phloem moisture are more important to brood production in fresh slash.

The amount of phloem moisture in living trees during dry periods in the summer and fall may have an important bearing on the incidence of five-spined engraver attacks. When drought strikes in late spring and early summer, entire stands of trees are undoubtedly affected adversely by lack of moisture and are more susceptible to beetle attack from mid-July to late fall. The degree of susceptibility probably varies with several conditions, among which stocking, age, tree class, and site may be important. In individual trees, the moisture deficiency may become more critical in the upper main stem, where attacks usually start, especially in trees larger than pole size.

The influence of phloem moisture deficiency on attacks was not demonstrated conclusively. Phloem moisture was measured at various heights on the stems of living trees, and in trees and stands representing varying degrees of susceptibility to bark beetle attack. These measurements were made principally in eastside-type pine from Lassen and Shasta Counties, and supplemental data were collected from westside-type pine in Madera County. Moisture determinations were based on dry-weight samples of phloem disks taken from test trees.

The most significant observations were as follows: (1) Consistent decreases in phloem moisture occurred as the seasons advanced in 1947 (dry spring and summer), while slight increases occurred in 1948 (wet spring, cool summer); (2) consistent differences in moisture were found at different tree heights, with least moisture in top and most at bottom; (3) trees growing in stands rated highest among 5 classes of beetle hazard (*5*) showed least phloem moisture, whereas trees in the next 3 classes of lesser hazard showed correspondingly higher phloem moisture; (4) no correlation with phloem moisture differences was shown among different tree classes (*7*) and risk classes (*10*).

Seasonal Temperature Conditions

Information on how temperature affects the development, behavior, and survival of broods is based on observational records and limited experimentation. While somewhat sketchy, the information serves to indicate the influence of seasonal temperature conditions.

Winter temperatures generally do not fall low enough to be lethal. A single record of the Oregon pine engraver (*Ips oregoni* (Eichb.)) a species closely related to the five-spined engraver, revealed no effect on a brood exposed to a minimum of 3° F.[6] Minimum temperatures throughout the range of the five-spined engraver are generally warmer than 5°.

Seasonal temperatures remaining between 40° and 65° F. for extended periods have been considered a cause of brood mortality.

[6] BUCKHORN, W. J. PRELIMINARY REPORT ON THE RELATION OF LOGGING OPERATIONS TO OUTBREAKS OF *Ips oregoni* IN PONDEROSA PINE FORESTS. Forest Insect Laboratory, Portland, Oreg. July 8, 1942. (Typewritten.)

This factor was judged important in limiting both the populations developed to maturity and the total number of generations in 1948. Actually, the effect of prolonged low temperature is probably indirect. While development of the insect is inhibited, other organisms, especially fungus, continue growth to such an extent that the food supply upon which the developing larvae depend may be exhausted before they reach maturity.

Experiments testing the behavior of adult beetles under controlled temperatures were conducted within tent enclosures in 1950 at Miami Field Base. These experiments showed conclusively that the optimum range for both flight and attacks is between 80° and 94° F. A marked decline in these activities was found at temperatures below and above this range. Brood development averaged 28 days, with 5 days for egg incubation, 15 days for larvae, and 8 days for pupae. The tests also showed that air temperatures above 95° tended to produce quiescence in adults. Activity was resumed at lower temperatures.

Winter Precipitation

The five-spined engraver ordinarily passes the winter period in the adult stage; mature larvae and pupae constitute only a small fraction of the total overwinter population. Occasionally young larval broods are produced late in the fall as a result of extended warm weather, but their numbers are reduced by winter moisture conditions resulting from saturating rains. A sudden decline of outbreak populations at Julian, Jerseydale, and in other parts of the California region in 1948 was attributed in part to the harmful effects of rain that soaked the inner bark of infested material. Examinations of numerous broods in slash and in attacked trees during January and February 1948 revealed heavy larval mortality.

Presence of Yeasts and Blue-Stain Fungi

That yeasts and blue-stain fungi commonly are associated with bark beetles has been known for many years, but the effect of these organisms on the success or failure of brood development is relatively unknown. The lethal effect on host trees of one of the blue stains (*Ceratostomella pini*) has been demonstrated experimentally (*1*), and this effect may have an important bearing on the development and maturity of the engraver beetle. The role of yeasts is still unknown, but for many years it has been suspected that yeasts may alter nutritional qualities of phloem so as to benefit bark beetles.

CONDITIONS AFFECTING OUTBREAKS

The causes of outbreaks of the California five-spined engraver beetle are not clear cut. In 1927, short-term localized or sporadic logging was recognized as a factor contributing to increased *Ips* attacks and killing in stands of living trees (*2*). At that time season-long operations were not considered hazardous to reserve pine stands, because beetles were believed to be attracted more readily by the continuously available fresh slash than by the living trees. Since

then, studies have revealed that attacks by the five-spined engraver as a rule do not follow this pattern. Severe outbreaks were observed several times in the same vicinity as season-long operations at the Jerseydale area, Mariposa County, Calif., from 1945 to 1948 (table 1). Serious infestations occurred in short-term logging areas in certain years and not in others, from 1944 to 1951. Still other outbreaks were observed during this period, but their origin could not be traced to any known source of fresh slash.

TABLE 1.—*Number of trees killed by the California five-spined engraver in Jerseydale, Calif., cutting areas, 1945–48*

Year	Area cut	Trees killed in reserve stand		
		Total	Per acre	Approximate percent of reserve
	Acres	*Number*	*Number*	
1945	300	0	0	0
1946	600	500	.80	1.6
1947	500	2,000	4.00	8.0
1948	400	12	.03	0

The studies since 1945 suggest that temperature and moisture are probably among the more important primary influences that determine the incidence and intensity of a five-spined engraver outbreak. Although the influence of these two climatic factors on the development and behavior of this insect has received some study, little is known about their effect on the host trees.

There is some evidence that soil moisture and outbreaks of the engraver beetle are related. Soil moisture was deficient in 1944 at the time of the outbreak in the Burney area (fig. 7). Records taken at a 9-inch depth revealed a moisture content slightly below the wilting coefficient for 2 months in late summer. Again, soil moisture was deficient in 1947, when this insect caused heavy damage, and above normal in 1948, when damage was very light. Therefore, adequate soil moisture during the growing season is believed to be a key factor in building up resistance of the host trees to attack.

Precipitation records may offer a way to forecast five-spined engraver outbreaks. Outbreaks between 1944 and 1949 in Trinity, Butte, Lake, Madera, and San Diego Counties in California were closely associated with accumulated deficiencies in total precipitation. Earlier records, dating back to 1913, in the Rogue River area in southern Oregon and in the southern Sierra Nevada indicated also that precipitation was associated with outbreaks. This evident association has resulted in the belief that it may be possible to predict an outbreak as early as May 1 by using the general precipitation pattern. This pattern is obtained by plotting the arithmetical accumulations of variations from the monthly means. However, such forecasts must also recognize temperature, population trend, and abundance of available slash material favorable to breeding.

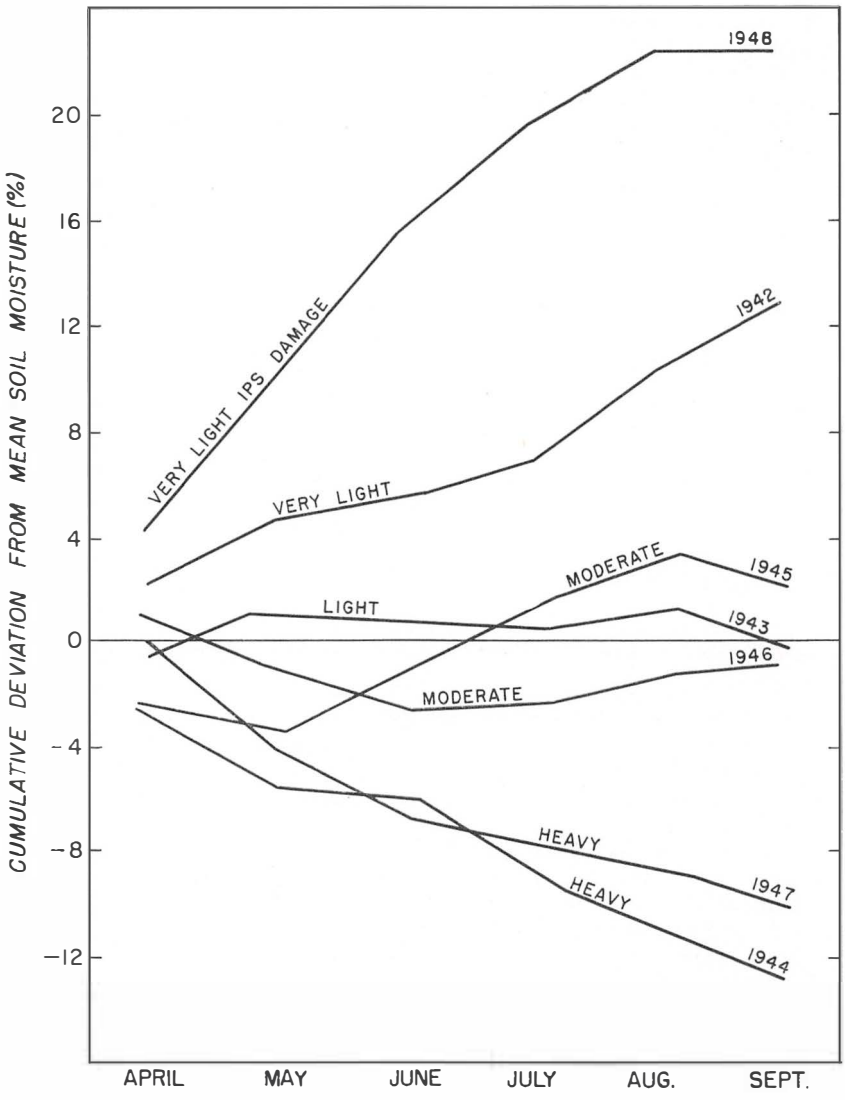


Figure 7.—Accummulated variation from monthly mean soil moisture associated with varying degrees of five-spined engraver damage in the reserve stand.

BIOLOGICAL CONTROL FACTORS

A number of parasitic and predatory insects enter the five-spined engraver's egg galleries and larval mines soon after the establishment of attacks and brood. Among these enemies of engraver beetles, insects of the Hymenoptera and Coleoptera orders predominate; some of the Diptera and Hemiptera are represented (table 2). In addition, many different species of insects enter trees infested with engraver beetles, to establish broods in bark, wood, or decay in organic matter.

Often this category of insects, known as associates, competes with engraver beetle broods for food, but the competition is generally unimportant as a control factor.

Among the predators, four species are more numerous and occur more consistently than the others. Three of these are in the order Coleoptera—*Thanasimus lecontei* (Wolc.), *Aulonium longum* Lec., and *Lasconotus laqueatus* Lec.; one is in Diptera—*Medetera aldrichii* Wh. No field tests or experiments were undertaken to determine the importance of any single species. However, comparative population data indicated a relatively higher degree of control by coleopterous species than by those belonging to other insect groups.

TABLE 2.—*Insect enemies and associates of California five-spined engraver broods, 1948*

Order	Family	Genus and species
PARASITES		
Hymenoptera	Braconidae	*Orgilis* sp.
		Coeloides brunneri Vier.
		Atanycolis anocomidis Cush.
	Pteromalidae	*Roptrocerus xylophagorum* (Ratz.).
		Roptrocerus eccoptogastri Ratz.
		Cecidostiba burkei Cwfd.
		Tomicobia tibialis Ashm.
	Eurytomidae	*Eurytoma* sp.
PREDATORS		
Coleoptera	Cleridae	*Thanasimus lecontei* (Wolc.).
	Colydiidae	*Aulonium longum* Lec.
		Lasconotus laqueatus Lec.
	Staphylinidae	*Phloeonomus* sp.
		Nudobius pugetanus Csy.
	Ostomatidae	*Temnochila virescens* (Fab.).
	Histeridae	*Platysoma punctigerum* Lec.
		Plegaderus nitidus Horn.
	Othniidae	*Othnius* sp.
Diptera	Dolichopodidae	*Medetera aldrichii* Wh.
	Lonchaeidae	*Lonchaea watsoni* Curr.
Hemiptera	Anthocoridae	Undetermined species.
ASSOCIATES		
Coleoptera	Scolytidae	*Ips* sp.
		Dendroctonus brevicomis Lec.
		Pityophthorus sp.
		Trypodendron sp.
		Hylurgops sp.
		Hylastes sp.
	Tenebrionidae	*Hypophloeus* sp.
	Cerambycidae	*Graphisurus* sp.
	Buprestidae	*Melanophila* sp.
	Curculionidae	*Cossonos* sp.
Diptera	Sciaridae	*Sciara* sp.
	Stratiomyidae	*Neopachygaster* sp.
		Undetermined species.

At times woodpeckers may become important in reducing highly localized beetle infestations in poles and saplings, but the birds are rarely seen working among infested slash. Occasionally, woodpeckers have wiped out more than 60 percent of the adult beetles concentrated in small-size trees, stripping away bark in the process and leaving the wood bare. Evidently exceptional, such activity is not likely to have a great deal of control effectiveness over wide areas. The California woodpecker (*Balanosphyra formicorora* Bairdi.) is the only species observed feeding on *Ips* (*9, p. 106*).

The amount of control by pathogenic organisms and the species involved are almost completely unexplored fields. Failure of five-spined engraver broods to develop has at times been atrributed to fungi, especially to common *Penicillium*-type molds, but limited attempts to determine their pathogenicity were unsuccessful. Other undetermined fungi in thick, moist phloem attacked by this engraver beetle were noted to develop with such rapidity that the deterioration of phloem was complete long before brood maturity. Heavy brood mortality appeared to result entirely from deterioration and contamination of food material in the host.

CONTROL METHODS

Control of five-spined engraver infestations can be accomplished by using practices that prevent development of broods in slash. Although this is an indirect approach, it is the soundest of any control method for this insect. The cost is but a small fraction of that of losses which may result in timber stands, or of the cost of direct control. Its success depends on the cooperative effort of timber owners.

Fresh slash from April to June is an indirect menace to adjacent living trees, since it serves to absorb emerging over-wintered beetle populations. In this material, the beetle breeds prolifically, with the result that high midsummer populations may cause serious killing in uncut stands nearby. Therefore, as a preventive measure, the best period for logging, thinning, and land clearing is from mid-July to late fall or winter.

Through the utilization of logs to an 8-inch top diameter, logging operations in second-growth stands can reduce surface areas suitable for engraver beetle broods by more than 50 percent. Modification of the remaining slash by lopping and scattering limbs and exposing main stem surfaces to solar radiation and drying may reduce to one-half the inner bark surface that is suitable for brood production. Adoption of these practices at the time slash is created will do much to eliminate engraver beetle infestations.

Preventive sprays can be used on accumulations of fresh slash in open piles or in partial shade. Mist or spray applications of a 5 percent solution of DDT in stove oil at a rate of 2 ounces per square foot of bark surface will prevent beetle attacks. This was demonstrated by Patterson [7] in 1948 when no successful attacks occurred on caged,

[7] PATTERSON, J. E. SOME EXPERIMENTS IN THE CONTROL OF SEVERAL WESTERN BARK BEETLES BY USE OF TOXIC SPRAYS. Forest Insect Laboratory, Berkeley, Calif. (Manuscript report.) April 1949.

treated logs 40 to 75 days after treatment. Complete success depends on thorough applications of sprays to all bark surfaces.

The direct control of five-spined engraver broods is at best a temporary measure to suppress heavy populations which, in combination with the western pine beetle, threaten widespread killing. The outbreak of these two species near Burney in Shasta County, Calif., in 1944 and the one near Julian in San Diego County in 1947 both exemplify epidemic combinations that required emergency action, but mainly to reduce the western pine beetle threat. Three methods that can be used when circumstances warrant are fell-burn, toxic penetrating oil applications, and salvage logging.

In the fell-burn method, fire is used to destroy the broods within and under the bark. Pole-size trees are limbed, cut into lengths convenient for handling, piled, and burned. Larger trees, especially those with western pine beetle infestations, are peeled along the upper log surfaces and the loose bark is distributed along the under sides of the log, then burned. Such burning must be done with care to minimize damage to adjacent trees and to avoid spreading fire beyond the confines of the treated trees. The work should be restricted to seasons when burning is not hazardous.

Toxic penetrating oil applications can be used in place of burning when cost, effectiveness, and safety make the applications more advantageous than fire. Their most effective use is on bark less than ¾ inch thick. Formulations in stove oil or diesel fuel giving the best results are 1 part orthodichlorobenzene to 6 parts oil and 1½ pounds ethylene dibromide to 5 gallons oil. These formulations are applied as a solid stream to upper surfaces only of logs as they are rolled until all the bark is saturated.

Salvage logging is often used to control infestations in trees that can be readily reached from roads. In some areas special portable equipment is used to facilitate rapid handling and loading of infested logs onto trucks. These logs are hauled away to the sawmill where they are sawn into lumber. In the milling process the slabs containing infested bark are destroyed in the burner. The effectiveness of this control method depends on prompt detection of infestations and on salvage before the insects reach maturity and emerge.

In summary, recommended measures for controlling potential outbreaks of the engraver beetle are as follows:

1. When practicable, cut young-growth pine after July 15.
2. Lop and scatter all limbs attached to fresh logging slash, trees felled in land clearing, windfalls, and tops broken by snow, as soon as possible, allowing maximum exposure to the sun.
3. In logging or salvage operations, utilize all logs to an 8-inch top diameter.
4. Keep accumulations of slash or green logs away from living trees and fell trees away from dense thickets of young growth.
5. When necessary, kill the broods by fire or by toxic oil applications.

SUMMARY

The California five-spined engraver beetle is native to southern Oregon and California. Its sporadic attacks in pine timber, especially ponderosa pine at elevations from 2,000 to 4,500 feet, are most often

associated with slash resulting from logging or clearing operations. In stands of mature timber, top-killing is characteristic of engraver attacks, whereas complete killing is common in young stands with trees up to 24 inches in diameter.

Although the engraver beetle has long been known, it has been considered merely a secondary bark-beetle species associated with the western pine beetle until recent times. Unprecedented logging from 1943 to 1951, especially in second-growth ponderosa pine, resulted in large accumulations of fresh slash, a favored breeding ground for the engraver beetle. Outbreaks of the beetle then killed pine trees on a scale previously unknown.

Special studies were started in 1945 to obtain information on the causes and characteristics of outbreaks and to determine the best practices to minimize damage. These studies were undertaken in northern, central, and southern California with emphasis on biology, ecology, and control of this insect. Much remains to be learned, but the information gained so far serves well as a basic guide in managing ponderosa pine stands where this insect may become a problem. The more important points determined and their application are as follows:

1. Fresh slash in the form of unlopped tree tops left as a result of logging operations from February to July is attacked heavily, beginning in April. The resultant broods develop to maturity and the adults emerge to attack and kill trees from midsummer on through fall. Severe outbreaks are also associated with slash resulting from windfalls, tree damage by snow, and land-clearing activities.

2. Outbreaks of the five-spined engraver are short-lived, seldom lasting longer than one year, but subsequent breeding by the western pine beetle may result in epidemic outbreaks of the latter insect.

3. Average seasonal development through most of the range of distribution is 3 to 4 generations, with 2 to 5 at the extremes of latitude, depending on seasonal temperatures.

4. Ecological factors favoring outbreaks are temperature and moisture conditions optimum to brood development and soil moisture below the amount required to maintain stands in a vigorous state of health.

5. Insect enemies, woodpeckers, adverse temperature and moisture, and possibly pathogenic organisms tend to check infestations, but never completely control them.

6. Indirect control through practices to minimize or prevent early season breeding can be effected by: (a) lopping tree tops, scattering limbs, and exposing bark surfaces containing infestations to full sun; (b) late scheduling of seasonal cutting operations; (c) use of toxic oil sprays to prevent attacks when practicable.

7. Direct control may be required if the western pine beetle threatens epidemic killing. Control may be accomplished by: (a) the fell-burn method; (b) use of toxic penetrating oils; (c) salvage logging.

8. The information learned from this and other studies reveals that it is possible to carry on preventive practices that will minimize the importance of the five-spined engraver as a hazard to living trees. Success will depend on the cooperation of timber owners and operators.

LITERATURE CITED

(1) CAIRD, R. W.
1934. PHYSIOLOGY OF PINES INFESTED WITH BARK BEETLES. Bot. Gaz. 96: 707–733.
(2) BUREAU OF ENTOMOLOGY, DIVISION OF FOREST INSECT INVESTIGATIONS.
1927. THE RELATION OF INSECTS TO SLASH DISPOSAL. U. S. Dept. Agr. Dept. Cir. 411, 12 pp.
(3) DOANE, R. W., VAN DYKE, E. C., CHAMBERLIN, W. J., AND BURKE, H. E.
1936. FOREST INSECTS. 463 pp., illus. New York and London.
(4) HOPPING, RALPH.
1928. INFLUENCE OF SLASH ON BARK-BEETLE OUTBREAKS. Forestry Chron. 4: 15–21.
(5) JOHNSON, P. C.
1949. DETERMINING THE BARK-BEETLE HAZARD IN NORTHEASTERN CALIFORNIA. Jour. Forestry 47: 277–284, illus.
(6) KEEN, F. P.
1938. INSECT ENEMIES OF WESTERN FORESTS. U. S. Dept. Agr. Misc. Pub. 273, 210 pp., illus. (Rev. 1952.)
(7) ———
1943. PONDEROSA PINE TREE CLASSES RE-DEFINED. Jour. Forestry 41: 249–253, illus.
(8) ———
1933. A NOTE ON THE HIBERNATION HABITS OF SOME ENGRAVER BEETLES OF THE GENUS IPS. Jour. Econ. Ent. 26: 297–298.
(9) PETERSON, R. T.
1941. A FIELD GUIDE TO WESTERN BIRDS. 240 pp. Boston.
(10) SALMAN, K. A., AND BONGBERG, J. W.
1942. LOGGING HIGH-RISK TREES TO CONTROL INSECTS IN THE PINE STANDS OF NORTHEASTERN CALIFORNIA. Jour. Forestry 40: 533–539.
(11) SWAINE, J. M.
1918. CANADIAN BARK BEETLES, PART II. Canada Dept. Agr. Ent. Branch Bul. 14, 143 pp., illus.

U. S. GOVERNMENT PRINTING OFFICE: 1955